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ABSTRACT This article summarizes the development of background limited infrared detection systems outside China, describing a number of infrared space detection systems. It primarily introduces long wave infrared focal plane array technologies. Finally, it puts forward our proposals.

KEY WORDS Infrared detection system, Infrared detector, Focal plane array, Z plane technology.

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I. INTRODUCTION

In the vast spaces of the earth's outer atmosphere, there are several thousand military satellites silently carrying out such work as reconnaissance, communications, navigation, map making, and so on. In the not distant future, outer space will see the appearance of space based kinetic energy weapons, space based laser weapons, and other strategic weapons. Moreover, the military activities of mankind will also break through the range of the atmosphere. Future wars will unfold in outer space and deep space. The weapons of space warfare include kinetic energy weapons, directed energy weapons, and strategic ballistic missiles. The targets of space warfare include various types of military satellites, space weapons platforms, and strategic ballistic missiles. The two attacking sides will make use of roughly the same weapons. However, the same weapons still have advanced and lagging portions. The differences can be very great. This is a basic factor determining victory or defeat in war. Similar to conventional war, in space war, there is also a question of who discovers whom first. This is a question of who first siezes the initiative. Moreover, the key to siezing the initiative lies in detection systems. At the present time, outside of China, use is made for the most part of background limited infrared detection systems in space. This article summarizes the development of background limited infrared detection systems outside China. As examples, it raises development cases associated with foreign space infrared detection systems. Moreover, it introduces the development status of key technologies associated with background limited detection. Finally, it puts forward our recommendations.

II. SPACE INFRARED DETECTION SYSTEM DEVELOPMENT [1-6]

The appearance of space shuttles and space stations as well as the rapid development of astronavigational technology laid--first of all, for such nations as the U.S. and the Soviet Union--a physical foundation to enter space and make use of it. Early--in 1964--the former Soviet Union set up a space defense department. In 1985, the U.S. established an (illegible) unified military space command.

In the 1950's, the U.S. started antisatellite research and development work. In 1977, implementation was begun of the F-15-MHV antisatellite project. This project is the firing from F-15 fighter planes of mini homing vehicles to intercept satellites (MHV). These are kinetic energy kill and damage devices which are not equiped with explosives (see Fig.1). MHV opt for the use of cylindrical fuselage structures. At the front end, there is an egg shaped cover. After firing, it is jettisoned. The interior of the cyclinder is equiped with 8 infrared telescopes. Long wave infrared detection devices carrying liquid nitrogen coolers are placed in the focal plane of 8 telescopes. Right

behind are microprocessors and laser gyroscopes. Outside the cylinder are installed 56 small cylinder shaped solid hydrazine pulse motors. After MHV separate from carrier rockets, they rotate at a speed of 20 turns a minute. 8 infrared telescopes are capable--against the background of extremely low temperature space--of gathering the infrared radiation of targets into long wave infrared detection devices. As a result, line of sight information supplied with regard to targets and interception devices--through laser gyroscope supplied inertial datums and microprocessor calculations--send out guidance commands to control the timely firing of 56 solid pulse motors to produce thrusts in order to collide with targets at relative velocities exceeding 10km a second.

The main path of antisatellite development in the former Soviet Union is using satellites to counter satellites. Beginning in 1968, the Soviet Union utilized "Cosmos" designation satellites to enter into orbits relatively close to target satellites. After that, maneuvers were carried out to change orbit. After it approaches the target satellite, the terminal guidance system of the "Cosmos" satellite locks on to the target. In conjunction with this, the satellite is guided, tracking and approaching the target. Finally, the combat section blows up, destroying the target satellite. Tests after 1976 opt for the use of infrared terminal guidance systems. /461

The U.S. star wars project (SDI) has a target surveillance, acquistion, tracking, and kill assessment (SATKA) system. It involves and includes--in the infrared--various types of radio spectrum detection, imagery, identification, and related optical system and signal processing technologies. Orbit altitudes associated with space surveillance and tracking satellites (SSTS satellites) in it are 10000km. Option is made for the use of 8 ■ 12 μm long wave infrared sensors utilized to carry out detection, identification, and tracking against warheads in the middle section of trajectories. In conjunction with this, target information is transmited to space based interception systems, causing them to carry out interception of the warheads. The technologies and equipment involved in them include telescopes, optical equipment, infrared focal plane arrays, cooling devices, and high capacity information processing systems. There is a requirement for optical aperture diameters to be 4m. Fields of vision are 4°x4°, resolution is 100m, and action range is 17000km.

In recent years, the U.S.--in consideration of such areas as expense and safety--has already canceled the SSTS project, replacing it with the brilliant eye (BE) detection satellite. The dimensions of BE satellites are only one tenth those of SSTS satellites. BE satellites weight 450kg. The original SSTS satellite was 18 tons. However, the number of BE satellites is 50 ■ 70. BE satellites are a space based detection system in the global protection system (GPALS) to defend against limited attacks. On them are installed multiple types of detection devices such as long wave infrared, ultra long wave infrared,

medium wave infrared, short wave infrared, visible light, ultraviolet ray, and so on. According to designs at the present time, use will be made of coaxial long wave/ultra long wave telescopes as well as visible light/medium infrared off axis

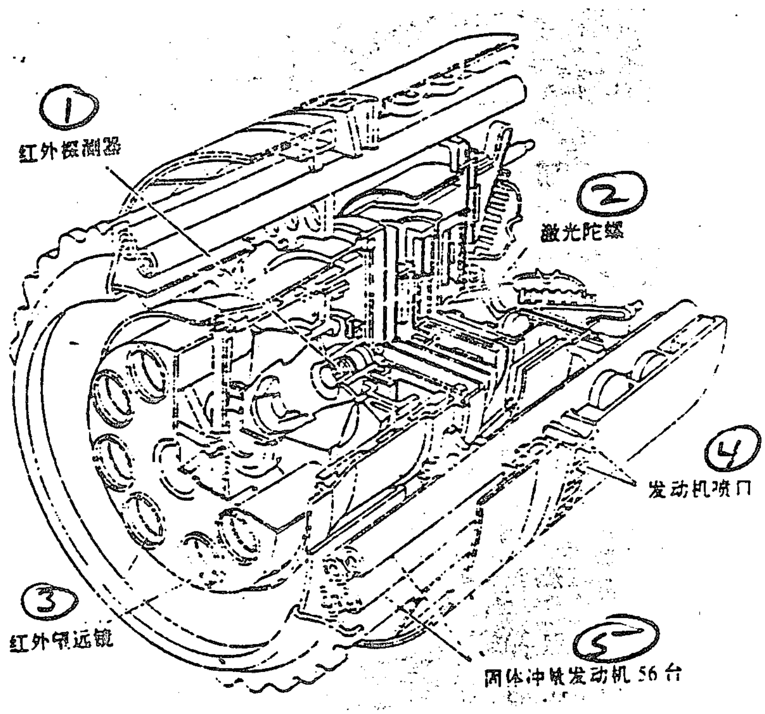

Fig.1 U.S. F-15-MHV Guidance Head Structural Diagram

Key: (1) Infrared Detection Device (2) Laser Gyroscope (3) Infrared Telescope (4) Motor Jet Port (5) 56 Solid Pulse Motors

telescopes to carry out target identification (see Fig.2). Long wave infrared detection devices associated with BE satellites opt for the use of fixed view arrays associated with 1.7 million image elements. Cooling by low temperature cooling devices is to 50K. This is higher by several orders of magnitude than current technological levels.

The HOE interceptor developed by the U.S. Lockheed missile and space company collided with a Minuteman missile warhead at an altitude of 100km above the Pacific on 10 June 1984 at a relative velocity of 3200km a second. This was the first time in the world that the warhead of an intercontinental ballistic missile had been intercepted by the use of a direct collision method. HOE interceptors opt for the use of long wave infrared silicon

adulterated detector arrays. They operate in the two wave bands of 8 ■ 14 μm and 16 ■ 20 μm and are liquid nitrogen cooled. The interception system outside the atmosphere (ERIS) is a further improvement and development of HOE interceptors. They are used for intercepts in the middle section of trajectories in order to facilitate the destruction of attacking missiles before they have entered the atmosphere. ERIS opts for the use of tellurium cadmium mercury detectors. It operates at the temperature of liquid nitrogen and can be cooled more easily than silicon /462 adulterates. On 28 January 1991, the U.S. carried out the first test of the ERIS interceptor missile to intercept a "Minuteman"-I intercontinental ballistic missile warhead. In conjunction with this, success was achieved. This test was carried out in a situation where there were countermeasures (decoys). Due to the fact that the missile in question opts for the use of such technologies as multiple optical spectrum imagery and pattern matching, it distinguishes very well between decoys and warheads. In warheads, there is a threat target diagram. Real and false targets are a certain distance from each other. On the missiles, long wave infrared homing devices and off axis type optical image telescopes take target imagery. Computers on the missile compare the target imagery obtained and target threat diagrams, searching out the real warhead targets. In the test in question, the target and decoy positions were already known. In the second ERIS intercept flight test on 11 May 1991, there was failure because of telemetry malfunctions. On 13 March 1992, during ERIS suborbital flight intercept tests, they were carried out in a situation where the location of a decoy balloon was not known before hand. Due to the location of the release of the balloon decoy being in error, it led to the interceptor missile deviating from the simulated nuclear warhead 2 ■ 3 m. It did not hit the target. Even though it missed the target, tests clearly indicate, however, that ERIS interceptor missiles are capable of distinguishing warheads and decoys. In conjunction with this, they are able to successfully track targets.

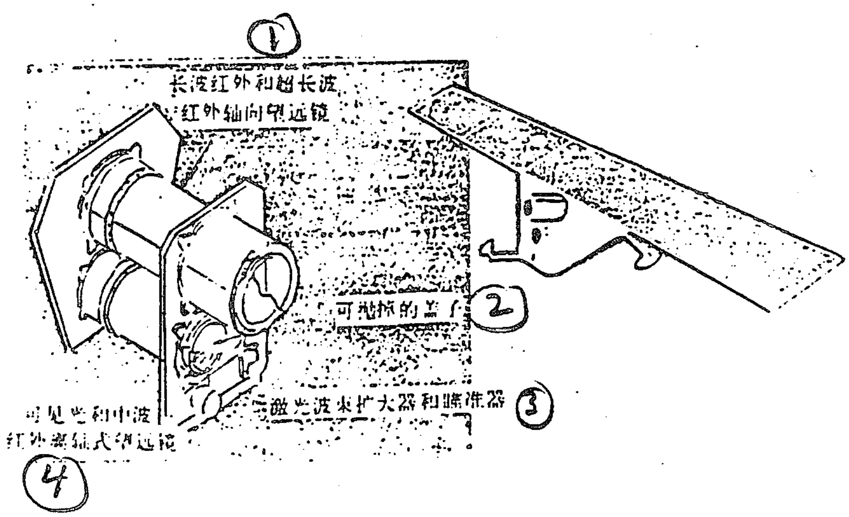

Fig.2 External Form and Structural Diagram of Brilliant Eye (BE) Satellite

Key: (1) Long Wave Infrared and Ultra Long Wave Infrared Axial Telescope (2) Cover that Can Be Jettisoned (3) Laser Beam Amplifier and Aiming Device (4) Visible Light and Medium Infrared Off Axis Type Telescope

On space battlefields, in order to destroy hostile military satellites, space based weapons platforms, laser weapon combat mirrors, as well as strategic ballistic missiles, and so on, there is a need for target monitoring, acquistion, and tracking systems. Use is made of kinetic energy weapons or ballistic missiles to act as attack weapons. When they arrive at predesignated points in space, it is necessary to opt for the use of homing terminal guidance technologies, guaranteeing guidance precision and the destruction of targets. Although radars, lasers, visible light detection systems, and so on are all capable of effectuating homing terminal guidance, infrared detection systems, however, which have been used by people in the

(military for long periods, are the most mature. In space applications, infrared detection systems not only possess good passive detection concealment characteristics as well as such advantages as high resolution and easy miniaturization, but, in states of ultra high vaccuum, they are capable of all weather operation. In particular, background temperatures associated with space are very low. It is possible to make use of infrared detection devices associated with background limited performance to carry out detection against long range space targets.

Military satellite orbit altitudes are generally 300 ■ 1000km. The altitudes of orbits associated with space based weapons platforms and laser weapon combat mirrors are 800 ■ 1000km. On the basis of a number of empirically measured data and roughly calculated estimates, the range of temperature changes associated with them is an approximate high of 360k and an approximate low of 145k. The temperatures associated with strategic ballistic missiles located in the middle section of trajectories also do not go out of this range. Taking these targets and looking at them as gray bodies, by the Wien displacement law, it is possible to estimate that what they are sending out is long wave infrared radiation with a wave length of 8 ■ 20 μm. Therefore, it is necessary to make use of long wave infrared detection devices. Only then is it possible to detect space targets.

Infrared nonimagery guidance takes targets and turns them into a point source, opting for the use of single variable infrared detection devices making use of radiated temperature differences between targets and background in order to acquire and track targets. This type of guidance technology is already widely used in air to air missiles and ground to air missiles. Infrared imagery guidance is capable of being divided into two catagories. One type is multiple unit infrared detection device linear array scanning imagery guidance. It uses a rotating disk type scanning device to carry out grating scan imaging for target information detected by infrared detection device linear arrays. The other type is multiple unit infrared detection device focal plane array imagery guidance. This takes infrared detection device arrays and signal amplifiers corresponding to each /463 detection device as well as processing circuits and integrates them together on an optical system focal plane. Opting for the use of electrical scanning to replace mechanical scanning saves a complicated scanning and adjustment mechanism. In conjunction with this, it is possible to use fixed view methods to detect satellites. The target identification capabilities and guidance precisions associated with infrared focal plane array (FPA) imagery guidance are higher. Action distances are farther. Counter jamming performance is better. Fields of view are wider. Volumes are smaller. The two D and T types of the MAVERICK AGM-65 air to ground missile developed by the U.S. Hughes company opt for the use of FPA imagery guidance, making use of 4x4 tellurium cadmium mercury detection devices. The operating wave band is 8 ■ 12 μm. They are capable of equiping for unit utilization. The

U.S. military not only thinks of using FPA imagery guidance in antitank systems, fighter aircraft, and armed helicopters. They also will use it in space based defense systems.

The U.S. ground surveillance and tracking system (GSTS) is one type of long wave infrared (LWIR) surveillance detection device. It is one part of the strategic defense system (SDS). GSTS is composed of detection devices, common use processors, guidance and detection subsystems, as well as communications subsystems. In it, detection devices are composed of telescopes. Telescopes take incoming electromagnetic radiation and focus it on a focal plane. Moreover, the focal plane is composed of several thousand individual detection elements. Detection elements (long wave infrared) take electrical signals and convert them into forms associated with appropriate common use processors. Detection devices are surrounded by deep cooling systems in order to facilitate maintaining their temperatures within required combat ranges. The functions of GSTS are search, acquisition, tracking, and target identification. In conjunction with this, data on detected attacking ballistic missiles is transmited to battle management, command, control, and communications (BM/C3) systems of SDS. It is capable of tracking incoming missile warheads in the middle phase and early final phase. At the same time, it is also capable of distiguishing warheads, defense penetration systems, and space junk.

From the above, it can be seen that space infrared systems opting for the use of long wave infrared focal plane array imagery guidance heads is appropriate.

III. BACKGROUND LIMITED INFRARED DETECTION AND RELATED TECHNOLOGIES [7-12]

Infrared detection devices are instruments that take incident infrared radiation signals and convert them into electrical signal outputs. They are detection components of infrared focal plane arrays. When targets are detected in space, due to the fact that they are located in an ultra high vaccuum, problems with atmospheric absorption do not exist. However, as far as solar irradiation is concerned, reflected radiation from the earth and other celestial bodies make space possess a certain ambient temperature. Added to the influences of various types of electromagnetic radiation and particle radiation, targets are put in the middle of a strong radiation background. Background radiation and signal radiation enter detection devices at the same time. Moreover, general background radiation is much stronger than signal radiation. It is then necessary to detect weak targets in strong backgrounds. Option is made for the use of a number of technologies capable of taking mean values for background radiation and filtering them out. However, there is still no way to eliminate the ups and downs in the mean values of background radiation photon densities. After background radiation fluctuations enter detection devices, they form background radiation fluctuation noise. Detection devices--in

and of themselves--have various kinds of noise. It is necessary to think of ways to lower noise associated with detection devices themselves, making detection device detection limits finally be set by background radiation fluctuation noise. When background fluctuation noise is just equal to signal, it then reaches background radiation fluctuation noise limits. At this time, the detection rates detection devices possess are designated background radiation limit detection rates.

The sources of noise in infrared detection systems have three parts--photon noise given rise to by signal and background radiation, noise produced by detection devices themselves, and noise in electric circuits after detection devices. Due to randomness reached by radiation quanta, it goes without saying that signal or background radiation both have rising and falling noise. With regard to background radiation limited detection devices, if background photon flux is reduced, detection rates will increase. The specific method of doing this is to opt for the use of cooling aperture limitations on detection device aperture angles, or the installation of cooled optical filter devices at the front end of detectors, inhibiting as much as possible background photon flux when target signal flux is not minimized. Noise associated with detection devices themselves includes thermal noise, Schottky noise, composite production noise, 1/f noise, temperature fluctuation noise, as well as vibration noise, and so on. Thermal noise is given rise to by current carrying secondary thermal movements. Temperature fluctuation noise is given rise to by detection device temperature fluctuations. Allowing detection devices to operate at low temperatures, these two types of noise can be reduced. Schottky noise is given rise to by the noncontinuous nature of photoelectron production. Through limiting aperture angles or installing light filter devices, it is possible to reduce this type of noise. The influences of 1/f noise are very great at low frequencies. Making detection system operating frequencies greater than 1000Hz, it is possible to reduce this type of noise. Vibration noise is given rise to be vibration and pulses. Making detection device lead lines and structures compact, it is possible to reduce this kind of noise. Production of a composite noise is given rise to by fluctuations associated with current carrying secondary productions and complexing. Through improving semiconductor material characteristics, raising technical /464 working quality, and lowering detection device operating temperatures, it is possible to reduce this kind of noise. Outside of China, various types of infrared detection devices have already approached or reached background radiation limits. Through such measures as limiting aperture angles or adding optical filter devices, it is possible to raise detection efficiencies further. Noise in electrical circuits after detection devices and noise in detection are similar. Opting for the use of low noise preamplifiers, and, in conjunction with that, operating at low temperatures, it is possible to resolve this problem.

Detection device background radiation limited detection rates are different following along with differences in background radiation strengths. Due to deep space background temperatures being only around 4K, detection rates associated with background radiation limited detection devices can increase several tens of times--even up to several hundreds of times--and long range detection of space targets is possible. At the present time, background limited detection systems outside China all opt for the use of long wave infrared imagery focal plane array technology. Focal plane array detection elements are long wave infrared background radiation limited detection devices. Besides that, relevent signal processsing circuits are also included. Although, at the present time, focal plane array structures have many kinds of forms, there is already a gradual application of optimum Z p]ane technology.

(1) 致冷机的主要性能指标	
致冷量 (2)	5W
工作温度 (3)	64.6K
输入到马达的电功率 (4)	220W
活塞振幅 (5)	3mm
没有负载时冷到 65K 的时间 (6)	22min
最低温度 (7)	39.5K
达到最低温度的工作时间 (8)	35min

Key: (1) Main Performance Indices Associated with Refrigeration Devices (2) Amount of Refrigeration (3) Operating Temperature (4) Electric Power Inputed to Motor (5) Piston Amplitude (6) Time Period Associated with Cooling to 65K with No Load (7) Minimum Temperature (8) Operating Time Period Associated with Reaching Minimum Temperature

In order to reduce various kinds of noise and reduce background radiation in background radiation limited detection systems, long wave infrared focal plane arrays, including in them such circuits as low noise preamplifiers, and so on, as well as optical subsystems must all operate in low temperatures. There is a need to opt for the use of liquid helium or liquid nitrogen refrigeration devices. For example--making use of Joule-Tangmulin (phonetic) refrigeration devices or Sitelin (phonetic) refrigeration devices--it is possible in all cases to cool below 80K. In these, sealed cycle microrefrigeration devices have already developed in to the third generation. Moreover, they

have already developed from an integrated type structure to a dispersed type structure, that is, taking infrared detection device refrigeration fingers and accompanying compressor vibrations and separating them. Through 20 years of efforts, the Dutch Phillips company and the U.S. Hughes company have successfully developed Sitelin (phonetic) refrigeration devices with long life, low vibration, and electromagnetic drive. In particular, it is the electromagnetic drive magnetic suspension Sitelin (phonetic) refrigeration devices developed by the Phillips company which overcome the two fatal drawbacks of vibration and life associated with the old generation of integrated type Sitelin (phonetic) refrigeration devices, turning them into the refrigeration devices with the best prospects in infrared space systems. The primary performance indices are seen in Table 1. Besides this, the U.S. and the U.K. have also carried out far reaching research on the use of separated position type Sitelin (phonetic) refrigeration devices in tellurium cadmium mercury infrared detection devices at 77K.

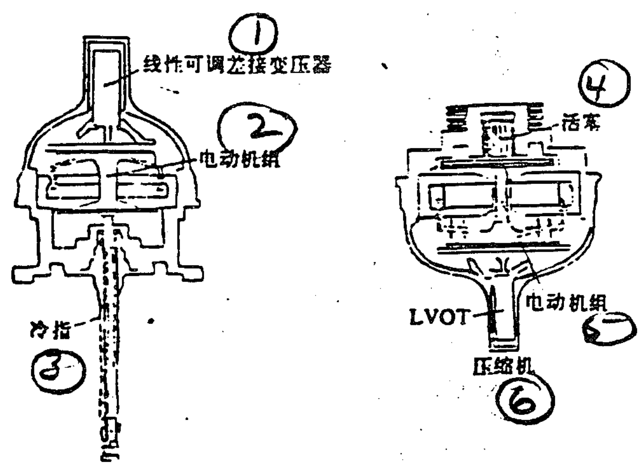

Fig.3 U.K. Developed Dual Drive Sitelin (phonetic) Refrigeration Device

Key: (1) Linear Adjustable Differential Transformer (2) Electric Motor Unit (3) Cold Finger (4) Piston (5) Electric Motor Unit (6) Compressor

In this, the U.K. in particular has ingeniously developed dual drive separate position type Sitelin (phonetic) refrigeration/465 devices (see Fig.3). The outside diameters of the cold fingers of the refrigeration devices in question are determined by infrared detection devices. The dimension is 6.7mm. It is possible to directly squeeze it into a glass Duwa (phonetic) bottle. The refrigeration device operating life exceeds 4000h. The overall life is over 10 years. It possesses very good helium seal characteristics. The leakage rate for the system as a whole will be smaller than 6.67x10-5 Pa■L/s. The refrigeration device power source is 220V, 400Hz, 3 phase. Input power is smaller than 80VA. The compressor piston stroke is 8mm. The exhaust device stroke is only 4mm. The exhaust device drive frequency is 52Hz. As far as position servo control circuits are concerned--from two displacement sensors--position signals are sent out in order to control the respective positions of compressor pistons and exhaust devices. The precisions can be better than 0.1mm.

IV. LONG WAVE INFRARED FOCAL PLANE ARRAY TECHNOLOGY [13■17]

Long wave infrared focal plane arrays (LWIRFPA) include two parts. One part is the rectangular array composed from long wave infrared detection devices acting as component detection assemblies. The other part is signal processing circuits related to detection elements. Seen from the point of view of structure, there are two types--single section and mixed. Single section models take infrared detection arrays and signal processing circuits and make them on the same piece of substrate. Mixed models opt for the use of different materials to respectively manufacture infrared detection arrays and signal processing circuits. After that, they are taken and connected together.

At the present time, the most advanced method for manufacturing single section model high precision focal plane arrays is silicon Schottky potential barriers. Infrared radiation wave lengths which can be detected are determined by potential barrier heights. Selecting appropriate metals, it is then possible to make Si-SBD respond to long wave infrared radiation. Japan's Mitsubishi company large scale integrated circuit research institute has already made 512x512 element IrSi focal plane arrays. In conjunction with this, they are already used in satellite remote sensing. The U.S. Lincoln laboratory and the Marshall science and engineering academy have cooperated in the development of 128x128 element arrays. Cut off wave lengths reach $10\mu m$. Operating temperatures are 50K. A striking advantage of Si-SBD focal plane arrays is the extremely good uniformity of focal plane response. It is capable of reaching 0.3%■2%. This very, very greatly lowers system requirements to compensate for nonuniform response between focal plane elements. A drawback is that sensitivites are an order of magnitude lower than other detection devices. By raising quantum yields, it is possible to improve Si-SBD degrees of sensitivity. In terms of

manufacturing technology, option is made for the use of extremely thin metal electrode structures, taking metal films and thinning them down from 80mμm to 10mμm. Again, coordinating with light cavity structures, it is then possible to make detection device sensitivities increase between ten and twenty fold.

Response wave lengths for photoelectric conductance of various types of silicon impurities can stretch to 28μm. Therefore, speaking in terms of principles, it is possible to make single section silicon infrared focal plane arrays--that is, non characteristic silicon focal plane arrays. Acting as one part of NASA's astronavigational technology development plan, the Hughes company's Si: Ca58x62 element array optical response range is 4 ■ 18μm. Operating temperature is 8K. Noise equivalent power is 2.0x10-17WH1/2 . Santa Barbara research center's Si:Sb 58x62 element array optical response wave length is 15 ■ 31μm. Operating temperature is 8K. Noise equivalent power is 2.7x10-17WH1/2 . The Rockwell company makes use of impurity belts to form photovoltaic effects associated with barrier layers, putting forward background irradiation type barrier impurity belt (B1B1B) focal plane arrays. This type of array is better than general non characteristic silicon arrays. Response characteristics are more uniform. Anti gamma radiation characteristics are better. The Rockwell company is what the U.S. space technology center uses in low background space detection. It developed a 50x10 element Si: As array. Operating wave length is 10.6μm. Operating tempeature is 12K. The detection rate is 6.7x1012cmHz1/2W-1 .

Although the performance of non characteristic silicon infrared detection devices is good, they are, however, only capable of operating at extremely low temperatures. Their utilization is very inconvenient. In order to raise operating temperatures, there is a need to opt for the use of characteristic semiconductor infrared detection devices. In general, the width of characteristic semiconductor restricted zones is great. There is no way to realize long wave responses. For example, among commonly used characteristic semiconductors, InSb restricted zone widths are the smallest. At room temperature, they are 0.18 electron volts. However, infrared radiation wave lengths they respond to only reach 7μm. Going through a long period of exploration and research, people /466 discovered that it was possible to opt for the use of Hg1-xCdxTe materials to manufacture long wave infrared detection devices. Hg1-xCdxTe ternary semiconductors are composed of mixed crystals of HgTe and CdTe. Their restricted zones change along with x values. They are capable of changing continuously from 0 to 1.59 electron volts. Long wave responses can easily extend to 25μm. Operating temperatures are raised to 77K. At the present time, option is made for the use of mixed type embedded array technologies. For example, the Texas Instrument company has already made 64x64 element and 64x120 element long wave arrays.

The U.K's Mullard Ltd. and the Royal radar signal research center has already test manufactured 32x32 element and 64x64 element long wave arrays. The 64x64 element long wave array test manufactured by the Honeywell company for the U.S. "star wars" project will be used in space based interception systems. In 1990, I.M. Baker and others had already developed 8 ▩ 12 μm wave band 128x128 element photovoltaic HgCdTe-Si mixed type focal plane arrays. Through making use of such advanced semiconductor manufacturing techniques as molecular beam extension (MBE), it is possible to make the surface areas of single section HgCdTe arrays get bigger and bigger. The U.S. Defense Department Advanced Research Planning Agency and the Strategic Defense Initiative Office (SDIO) view this very seriously, already investing several hundred million U.S. dollars to use in research associated with HgCdTe focal plane arrays.

On infrared focal plane arrays--besides detection element arrays--there are also information processing circuits related to detection elements. Different signal processing circuits have different methods in reading signals. At the present time, frequent use is made of the four types of reading methods below. (1) Utilization of charge coupling devices (CCD). Due to the great maturity of silicon integrated circuit technology, it is possible to take silicon detection device arrays and silicon CCD and make them on one crystal section. Opting for the use of Schottky potential barrier diodes, photovoltaic diodes, or metal-oxide-semiconductor (MOS) devices, in all cases, it is possible for them to act as photoelectric conversion devices. CCD are one type of device which use charge inclusion forms to store and transmit information. They are capable of taking photoelectric space changes and converting them into electrical signals that change as a function of time. Readout is carried out in order and is not random. There are transfer losses. (2) Utilization of MOS devices. In single section model arrays, MOS devices not only play photoelectric conversion roles, they also play signal readout switch and x,y addressing roles. In mixed model arrays, primary use is made of MOS multiple circuit conversion devices to act as switches and to carry out x,y address searches. The advantages of making use of MOS devices are that dynamic ranges are large, manufacture is easy, and random storage and access are possible. The drawback is that noise is heavy. (3) Utilization of two metal-insulator-semiconductors (MIS). Each image element makes use of two mutually coupled MIS structures to act as photoelectric conversion, storage, and read out devices. On the grids of MIS devices, pulse voltages are added, forming potential wells associated with the storage of electrical charges. Signals can advance directly from the back cover. They can also be random. Due to the lack of signal transmission processes, there are no transfer problems. (4) Utilization of single MIS devices. As far as arrays are concerned, each image element only requires making use of a single MIS device. MIS devices not only play photoelectric transfer functions, they also play signal read out functions. During read out, addresses are sought by

surrounding circuits. Read out efficiencies are high. Opting for the use of additional silicon time delay integration (TDI) circuits, electrical charge capacities are very large.

V. Z PLANE TECHNOLOGY [18■20]

What is called Z plane technology is nothing else than taking an infrared focal plane array and related signal processing circuits and making them into one three dimensional module. In infrared detection systems, there are two outstanding problems--that is, dynamic range and target extraction. Apparent infrared strength changes associated with space targets and backgrounds can sometimes reach several orders of magnitude. This then requires detection device array signal processing circuits to possess high dynamic, signal strengthening, static and noise suppression capabilities. Moreover, following along with increases in FPA densities, signal processing circuits must handle amounts of information collected by arrays which get bigger and bigger. This then led to people exploring ways to manufacture three dimensional signal processors.

In the early 1970's, the U.S. Air Force RM-208 project supported the Rockwell company in beginning research on Z plane technology. In 1978, the Grumman aviation and astronavigation company manufactured signal processing mixed integrated circuits on ceramic substrates. Detection devices were taken and attached on the edge of each mixed integrated circuit. After that, test measurements and adjustments were done. Finally, these mixed integrated circuits carrying detection devices were piled up to form a component. However, components making use of multiple layers of ceramic substrate were very cumbersome and heavy. With regard to missile systems, they are not ideal. Finally, the Irvine sensor company and others opted for the use of mature technology associated with semiconductor integrated circuits to resolve this problem. They first manufactured single section signal processor silicon integrated circuits. After that, each circuit section was taken and thinned down to the equivalent of FPA detector line spacing. It was then possible to take /467 these single section circuits and layer them up over each other. Finally, an FPA was installed on the side of a stacked up layer component. This type of technology has been designated as mixed embedded silicon layer superposition (HYMOSS) technology. This kind of technology provides a single independent analog signal

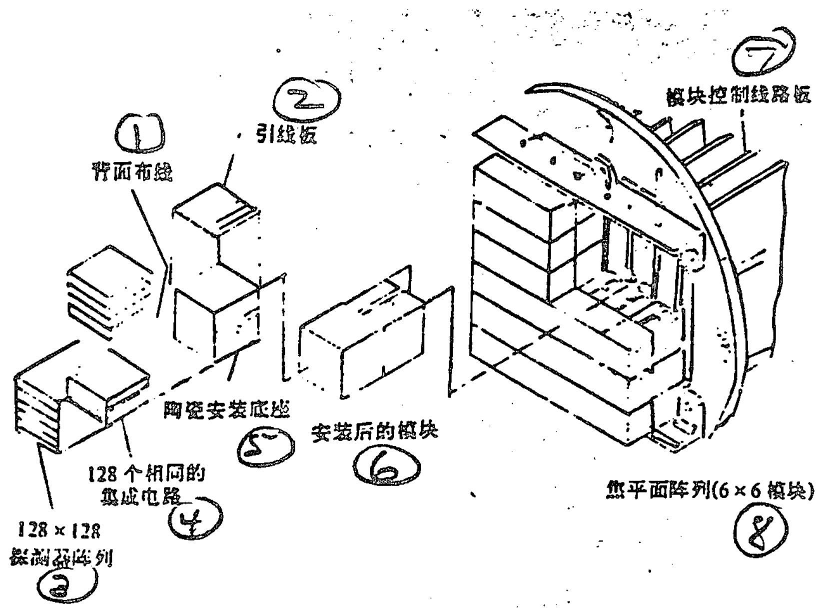

Fig.4 Z Plane Modules and Focal Plane Arrays

Key: (1) Back Surface Wiring (2) Lead In Plate (3) 128x128 Detection Device Array
(4) 128 Identical Integrated Circuits (5) Ceraminc Installation Base (6) Module After Installation (7) Module Control Circuit Plate (8) Focal Plane Array (6x6 Modules)

processing channel for each image element in FPA. The concrete way of doing this is to make multiple identical parallel signal processing channels on a single silicon integrated circuit chip. After that, take many of the same kind of single circuit chips and superimpose them to form a component. Then, take an FPA and

connect it up to the side of this component, forming a module. The Martin Marietta space flight group space systems company also opts for the use of HYMOSS technology. Fig.4 shows that the company in question uses a 128x128 element detection device array and 128 section signal processing integrated circuits having 128 identical channels. Fig.5 shows a situation where each channel includes transimpedance amplifiers (TIA), adaptive band pass filters (ABPF), threshold comparators (TC), integrators (INT), track and hold devices (T/H), and incident indication generators (EFG). Finally, signals are read out to external module control circuits (MCE). A schematic for a typical Z plane technology FPA module and electronics manufactured by the Irvine sensor company is seen in Fig.6. In various types of microassembly technologies for military use, HYMOSS techniques are already known for seal forms of the highest density. Each single section integrated circuit is capable of being thinned down to 50μm. A superimposed layer assembly formed from 128 layers of this kind of circuit is only 6.5mm thick. At the present time, HYMOSS technology is just in the midst of developing from 128x128 element arrays to 256x256 element arrays.

In the area of HYMOSS technology, the Irvine sensor company is far, far in the lead, drawing attention from the U.S. Air Force Weapons Laboratory (AFWL). AFWL uses infrared guidance heads equiped with HYMOSS modules to carry out dynamic fixed view tests. It was discovered that they are capable of increasing missile acquisition range, increasing sensor data handling capacity, have extremely good noise and static suppression capabilities, are structurally simple, and convenient for test measurements. AFWL believes that this technology is already mature and has decided to use it in air to air missiles.

VI. CONCLUDING REMARKS [21,22]

The 21st century is the new era of space flight for mankind. Technologically developed nations will all vie with each other to develop space enterprises, competing with each other to become the great powers of space and partake of the resources of space. They will not only continue to develop space defense systems. They will, moreover, do research on offensive space weapons. Because of this, ground warfare will expand into outer space, creating an integrated warfare of sea, land, and air. Going through many years of research and comparison, people /468

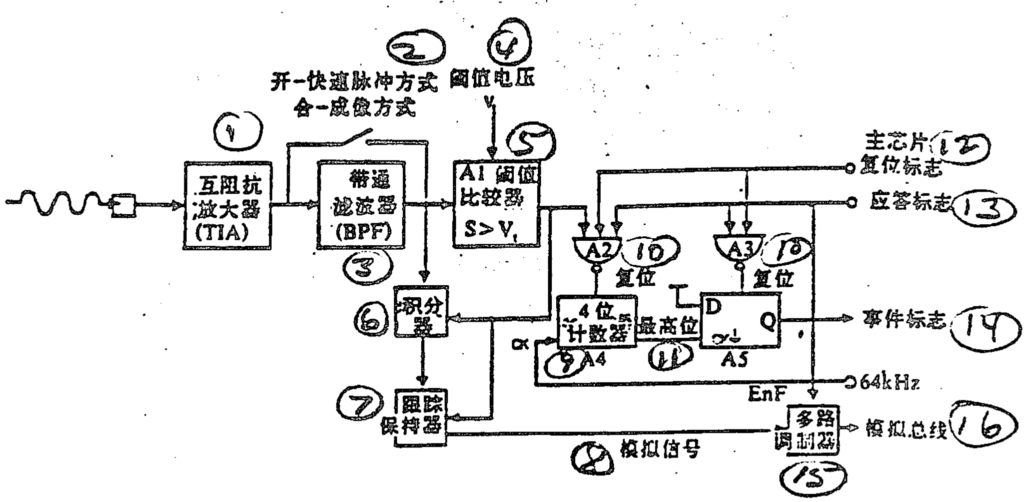

Fig.5 Analog and Digital Circuitry Used in Each Detection Channel

Key: (1) Transimpedance Amplifier (2) Open--High Speed Pulse Method Closed--Imagery Method (3) Band Pass Filter (4) Threshold Value Voltage (5) Threshold Value Comparator (6) Intergrator (7) Track and Hold Device (8) Analog Signal (9) 4 Position Calculator (10) Reset (11) Highest Position (12) Main Chip Reset Indication (13) Response Indication (14) Event Indication (15) Multichannel Modulator (16) Analog Main Line

believe that long wave infrared homing terminal guidance technology is the foundation for space weapons. The key components of long wave infrared imagery homing terminal guidance systems are long wave infrared focal plane arrays. A number of great nations have gathered together a large group of outstanding scientific and technical talents, doing research on and developing infrared focal plane array technology. This technology primarily includes long wave infrared detection device arrays and signal processing technology. In order to guarantee high reliability and the realizing of miniaturization, optical structures and refrigeration equipment must also improve constantly. There is a need to increase guidance head detection distances in space and deep space. Sensitivities of detection devices must be raised. That is also nothing else than needing to make long wave infrared detection devices realize background

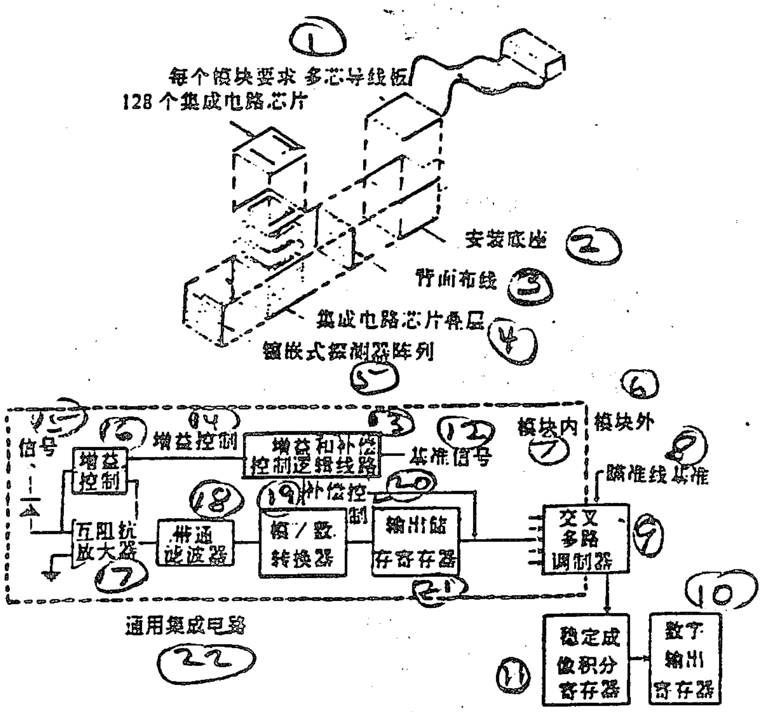

Fig.6 Schematic for One Z Plane Technology FPA Module and Circuits Manufactured by the Irvine Company

Key: (1) Each Module Requires Multiple Chip Lead Line Plates and 128 Individual Integrated Circuit Chips (2) Installation Base (3) Back Surface Wiring (4) Superimposed Integrated Circuit Chip Layers (5) Inlay Type Detection Device Array (6) Outside Module (7) Inside Module (8) Alignment Line Datum (9) Crossover Multichannel Modulator (10) Digital Output Register (11) Stable Image Integration Register (12) Datum Signal (13) Gain and Compensation Control Logic Circuit (14) Gain Control (15) Signal (16) Gain Control (17) Transimpedance Amplifier (18) Band Pass Filter (19) Analog/Digital Convertor (20) Compensation Control (21) Output Storage Register (22) Common Use Integrated Circuits

radiation limited operation. This is the most basic and also the most important operation. Besides this, it is necessary to realize intelligent tracking. This is the basic way to raise kill probabilities.

We are a great nation. We must not only win honor for our country in space activities and make contributions for mankind, we must also make appropriate preparations for space wars of the future. To this end, we make the following suggestions.

1. Our department already has over a 20 year history of carrying out research associated with countering satellites and countering missiles. A good number of gradual successes have been achieved. Even more important is that a group of oustarding cadre have been developed. These people have rich experience and extensive knowledge. They are a national treasure. They should be allowed to return successively to research work associated with space combat weapons, assuming leadership of various projects, bringing their knowledge and talent into play, and bringing up a group of young people, giving posterity to our enterprise.

2. Although--besides infrared terminal guidance, there are also many types of guidance methods such as visible light, laser, as well as millimeter wave, and so on, and, moreover, composite guidance is capable of capitalizing on strengths and avoiding shortcomings, and is an important direction of development--on the basis of our national situation, however, our department should concentrate personnel strength and materiel to do long wave infrared homing guidance systems. This type of system is capable of adapting to the basic requirements of future space warfare. At the same time, it will also lay a firm foundation for going a step further to opt for the use of composite guidance technologies. Our department possesses rich experience in management and practical actualization associated with the development of infrared terminal guidance systems. There is an enormous research contingent, and there are very strong development and production capabilities. Of course, infrared imagery search, tracking, and precision guidance is a high technology. It involves the newest modern optical, mechanical, and electrical techniques. It is necessary to set out from the requirements of overall system performance, coordinating the technical parameters associated with various subsystems, to put forward technical requirements that are realistically feasible. With the coordination of relevent units domestically, breakthroughs will be made one by one in key problem areas, catching up to and surpassing advanced world levels.

3. Our department must give full cooperation to the Academy of Sciences and the relevent research institutes of general electronics companies, first of all overcoming the key technologies associated with long wave infrared Joule plane

arrays. Strength should be concentrated on doing long wave tellurium cadmium mercury background radiation limited detection devices. Being limited to the semiconductor industry level currently existing in China, we opt for the use of detection element embedding technology and Z plane technology, developing mixed model long wave tellurium cadmium mercury infrared focal plane arrays as being comparatively appropirate--not only easy to realize but also capable of matching up with the requirements of space homing terminal guidance systems.

4. As far as studies on long wave tellurium cadmium mercury detection devices is concerned, it is necessary to put work into materials research. Due to high mercury vapor pressures and easy cadmium liquation, it is difficult to make crystals which have both uniform structures and photoelectric characteristics. There is a need to carry out research to resolve key problems in such technology areas as molecular beam extension (MBE) as well as metallic organic chemical vapor deposition (MOCVD), and so on, developing as early as possible tellurium cadmium mercury thin film materials with relatively large surface areas and uniform properties.

5. Development directions associated with space warfare weapons should require detection systems which possess even larger focal plane arrays, even longer operating wave lengths, even more numerous focal plane processing functions, even higher counter radiation capabilities, and even lower power consumption. Outside China, there are people who have done some work in the areas of superconducting detection devices and superconducting circuits. In the laboratory, high speed wide band superconducting detection devices, high sensitivity preamplifiers, and high speed A/D convertors have been made. At the present time, option is made for the use of superconductor Niobium (Nb). Operating temperature is 4K. With option made for the use of niobium nitride, operating temperature is 8K. We should know about the advantages of small volumes possessed by superconducting detection devices and superconducting circuits, the extremely low powers, the very high speeds, and the inherent counter radiation capabilities, making use of China's dominance in the field of superconduction research to develop work in this area.

6. Space warfare weapons should possess their own survival capabilites and autonomous combat capabilities, that is, they must possess--in situations with complex backgrounds--accurate identification, reliable acquisition, precise tracking and guidance, as well as capabilities to attack vital locations on targets along with the ability--when needed--to maneuver and evade. This then requires that computers carried on missiles possess capabilities associated with learning, connected thought, inference, as well as adaptation to target changes and changes in the space environment--that is, possess artificial intelligence. China has dominant positions in the areas of computer software engineering and artificial intelligence. All that is needed is a detemination to do it. It is then possible to gradually realize

a conversion of space combat weapon homing guidance to intelligence. /470

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